

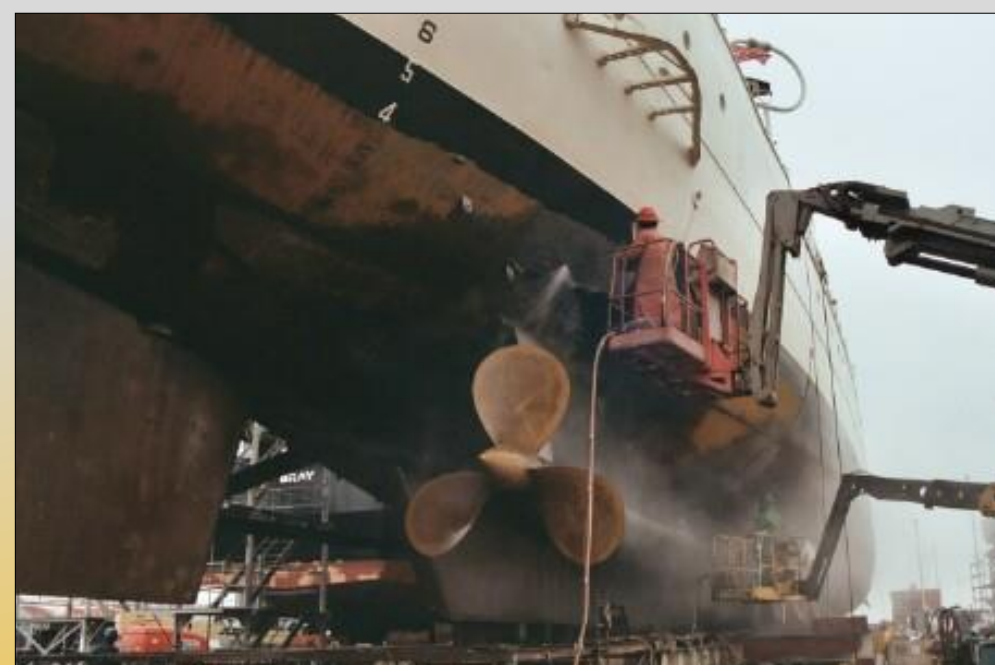
Controlling the Corrosion of Metals with Polyphenolic Proteins

Name: William F. Nelson

Advisor: Dr. Douglas C. Hansen

The Problem: Flash Rust

- When old paint is stripped from the hulls of ships, rust can quickly form on any exposed metal surfaces
- Before ships can be repainted, rust must be removed, which can incur significant costs
- There is a need for an environmentally friendly flash rust inhibitor that can also promote the adhesion of subsequent coatings



Objectives

- Determine the effectiveness of different protein compositions at inhibiting the corrosion of high-strength steel alloys
- Examine the effect of crosslinking on the performance of the protein treatments
- Test several different formulations of proteins/polypeptides to obtain an optimal formulation for flash rust inhibition

Methodology

Several techniques will be used to judge the performance of the marine proteins and polypeptides.

- Exposure chamber tests will be used to determine what combinations and concentrations successfully inhibit corrosion in an environment somewhat similar to that encountered in the field.

Data gathered from exposure chamber tests:

- Corrosion morphology
- Mass loss
- Time-to-corrosion

- Electrochemical data will be collected on protein films in a seawater electrolyte for successful formulations. These techniques will give more information about how the coating affects the kinetics of the reaction and how the permeability of the coating to water changes over time.

Electrochemical Techniques used:

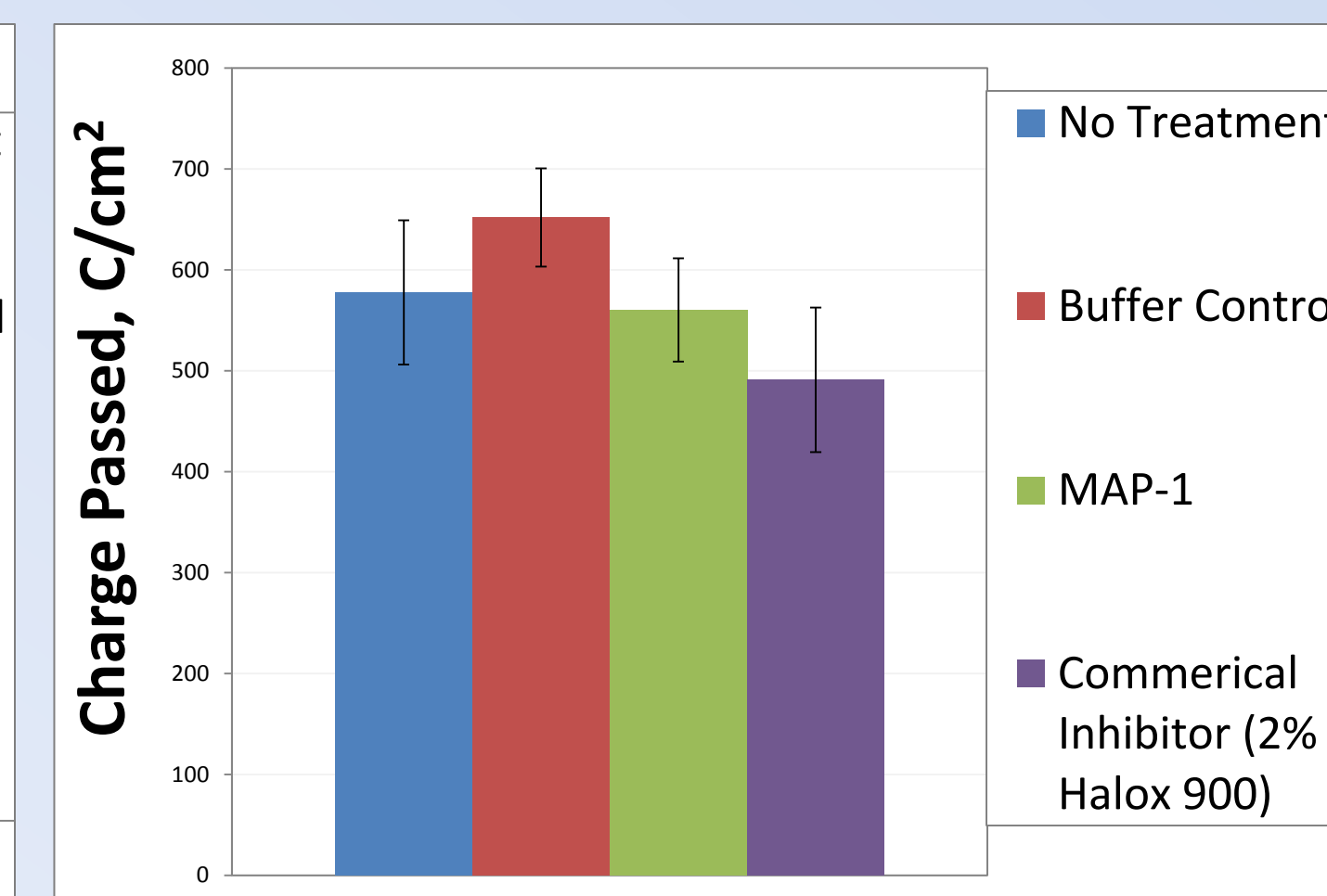
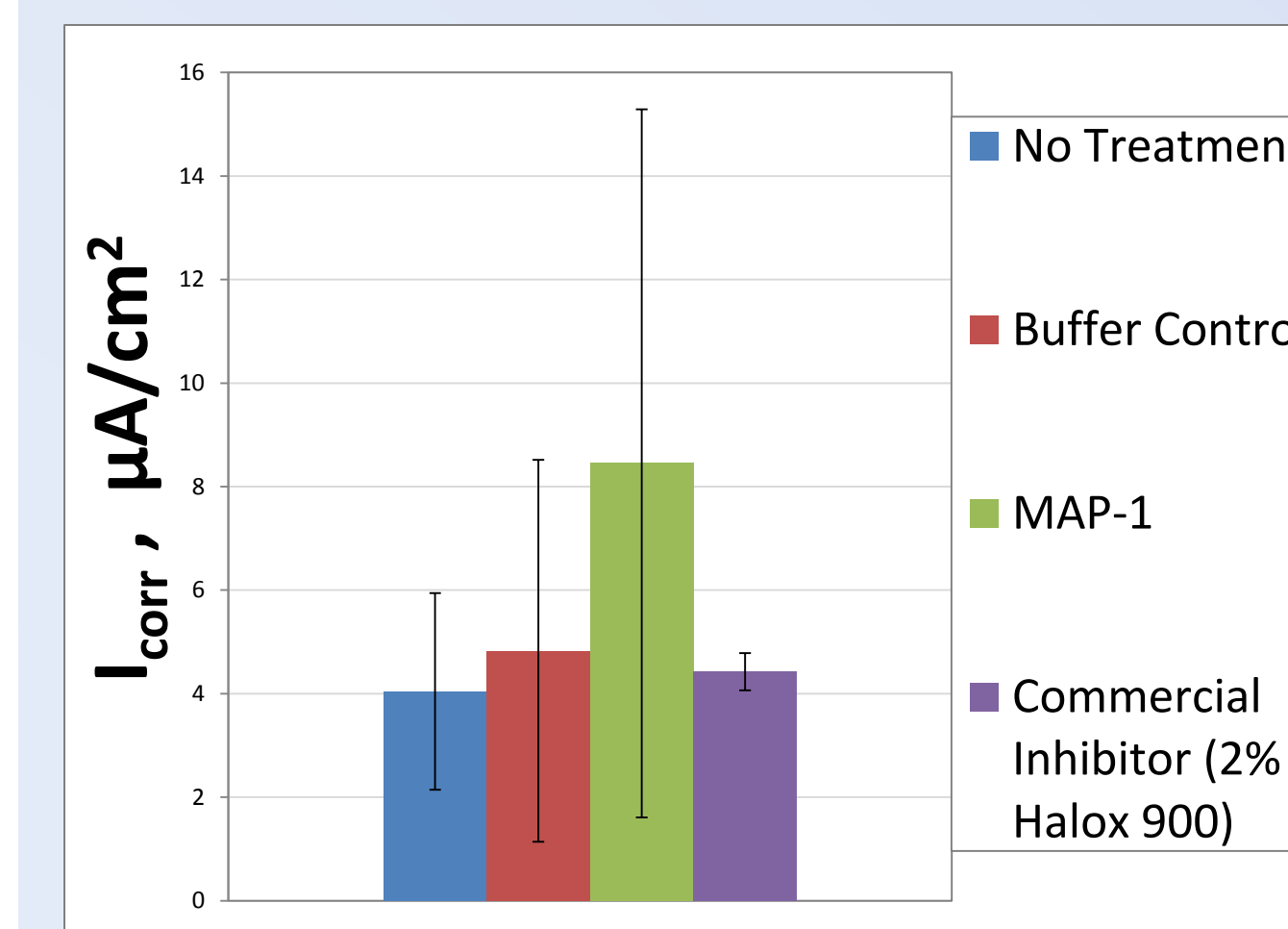
- Cyclic potentiodynamic polarization

Electrochemical Data

Cyclic Potentiodynamic Polarization

In an electrochemical cell, the sample is polarized anodically (facilitating oxidation) up to a set potential, typically causing coating failure

- Mass loss and total charge passed data can be collected
- Shape of the curve gives information on surface conditions
- Corrosion current measurements can be made



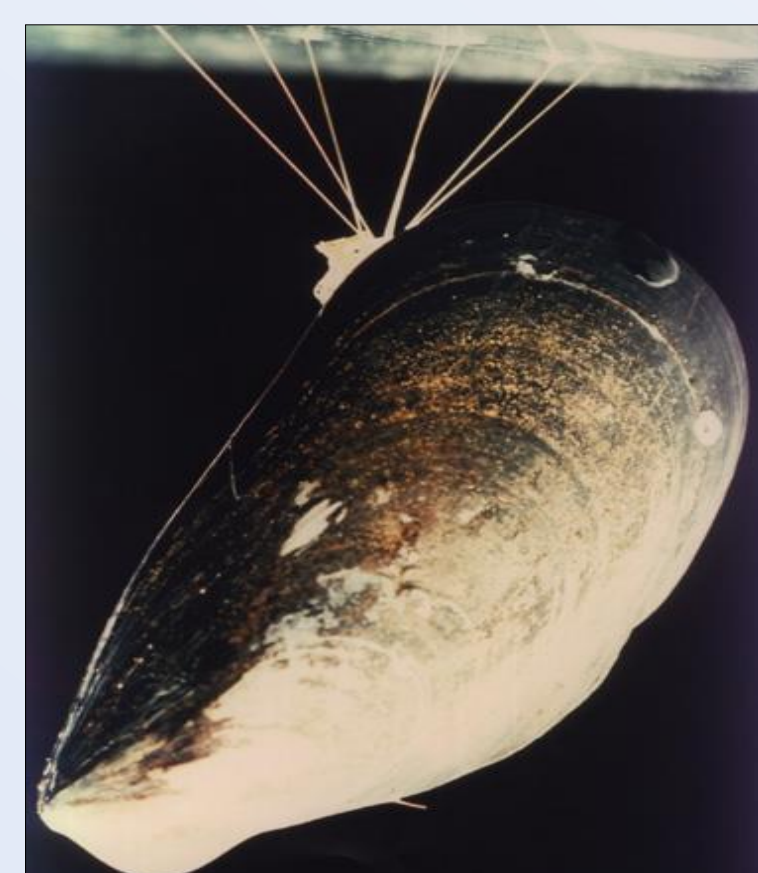
Marine Adhesive Proteins: A Possible Solution

Proteins from marine organisms such as blue mussel *Mytilus edulis* have been shown to inhibit the corrosion of stainless steel¹. These proteins contain an amino acid, L-Dopa, which confers two unique properties to the protein:

- Chelation: L-Dopa forms strong bonds to metal ions, allowing it to adhere strongly to a metal surface and inhibit corrosion
- Crosslinking: L-Dopa can participate in enzymatically catalyzed reactions that knit together separate stands of protein, creating a barrier to ionic diffusion

Polypeptides from the sea squirts *Molgula manhattensis* and *Styela plicata* will also be investigated. These polypeptides are generally smaller than the proteins from *Mytilus edulis*, but they have a higher L-dopa content

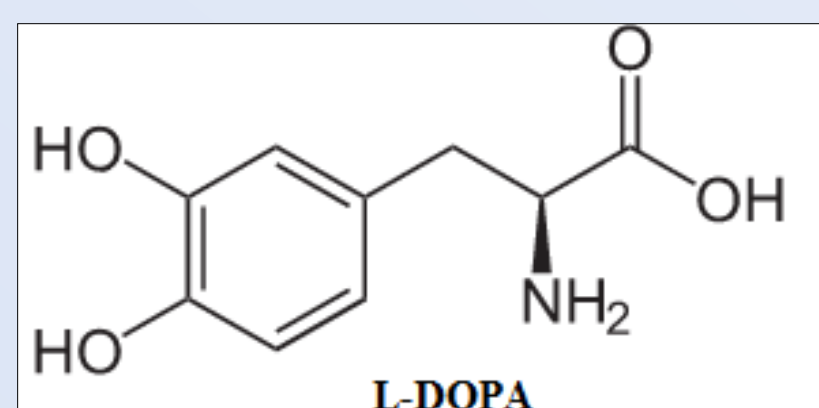
Mytilus edulis Foot Protein 1 (MeFP-1) has a repetitive amino acid sequence of Ala-Lys-Pro-Ser-Tyr-Hyp-Hyp-Thr-L-Dopa-Lys, giving it many possible attachment methods besides L-dopa (e.g., H-bonding). It also has a random coil conformation which maximizes the availability of its functional groups for adhesion.



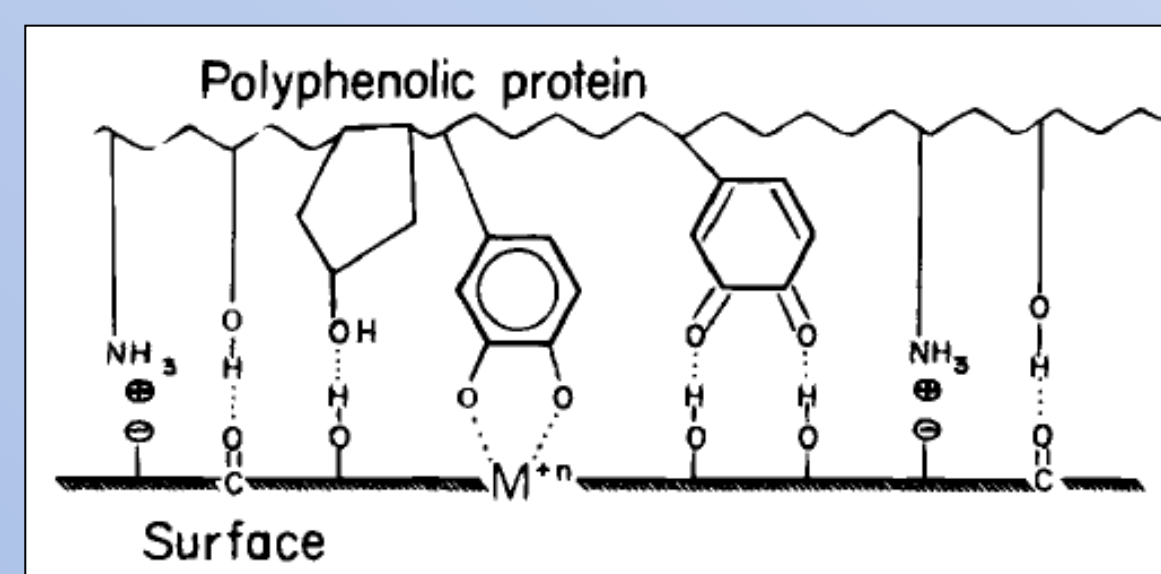
Mytilus edulis



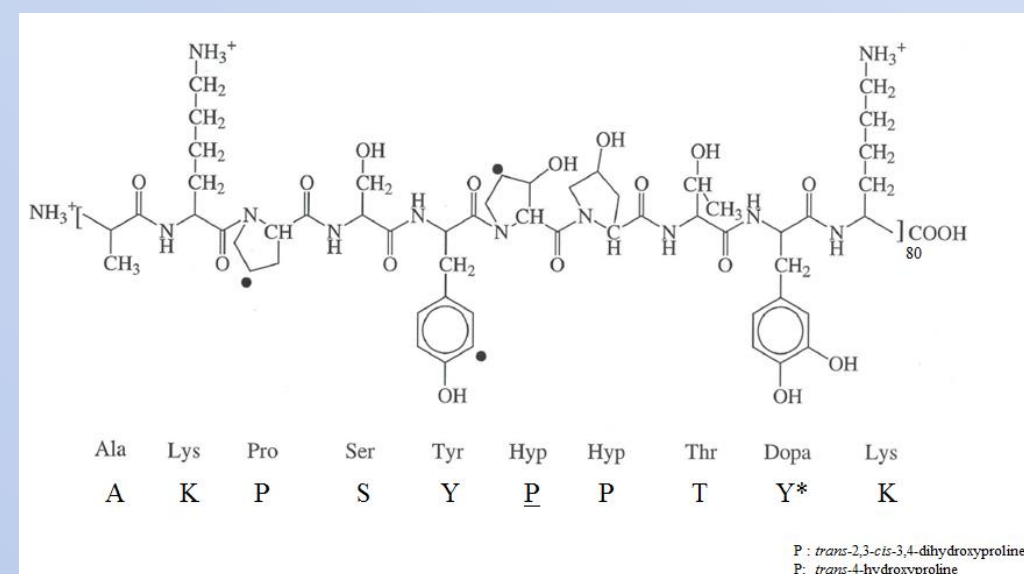
Molgula Manhattensis



L-Dopa



Graphic showing some of the various surface interactions available to marine adhesive proteins



The repeated decapeptide expressed in MAP-1¹¹

Table 1: The various marine proteins considered in this research^{2,3,4,5,6,7,9,10}

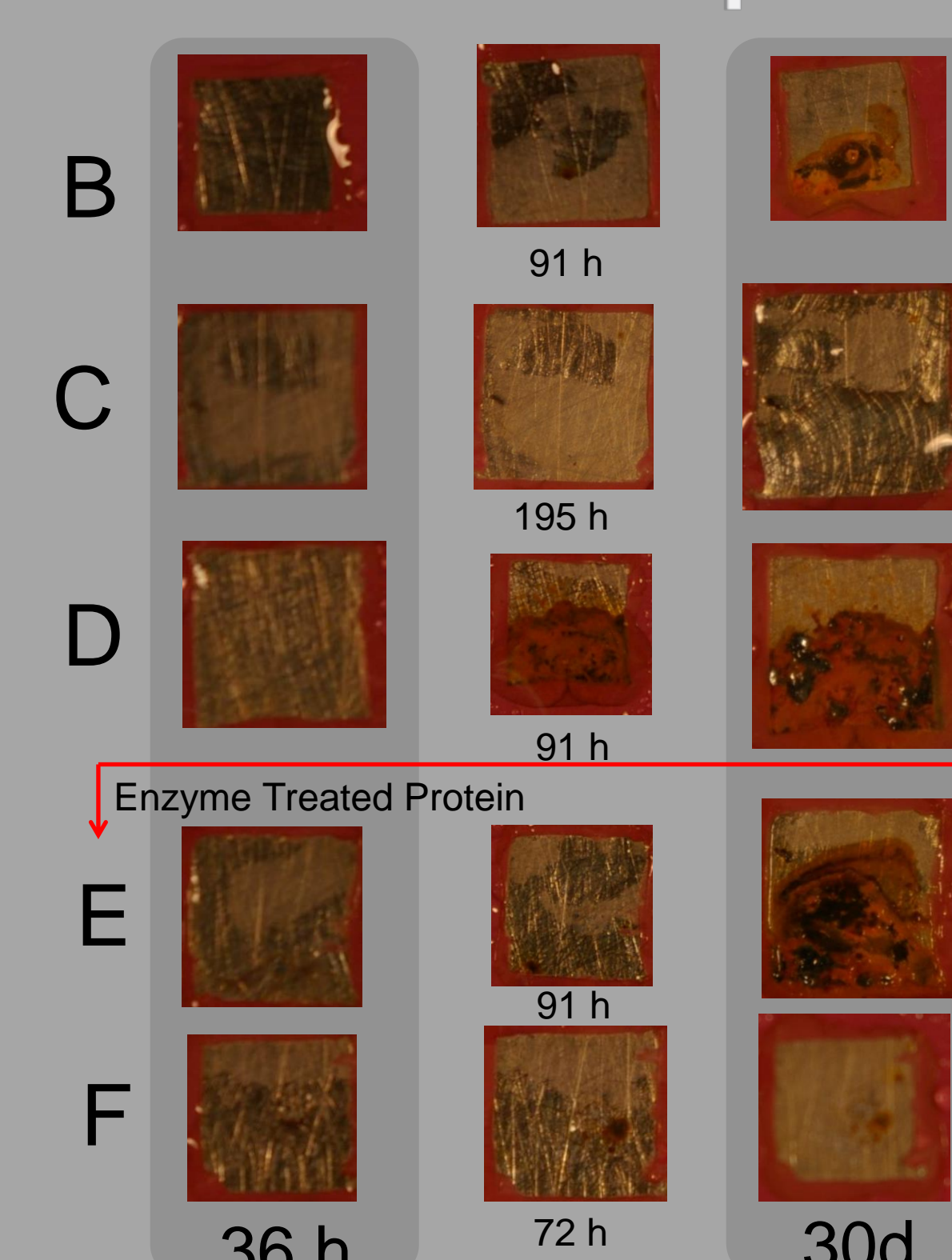
Protein	Source	Molecular Weight (Da)	% L-Dopa
MeFP1	<i>Mytilus edulis</i>	110,000	13%
MeFP-2	<i>Mytilus edulis</i>	45,000	3%
MeFP-3	<i>Mytilus edulis</i>	6,000	21%
MeFP-4	<i>Mytilus edulis</i>	80,000	5%
MeFP-5	<i>Mytilus edulis</i>	9,500	27%
Min-1	<i>Molgula manhattensis</i>	6,000-11,000*	40%
Sp-1	<i>Styela plicata</i>	6,000-11,000*	60%

*Estimated

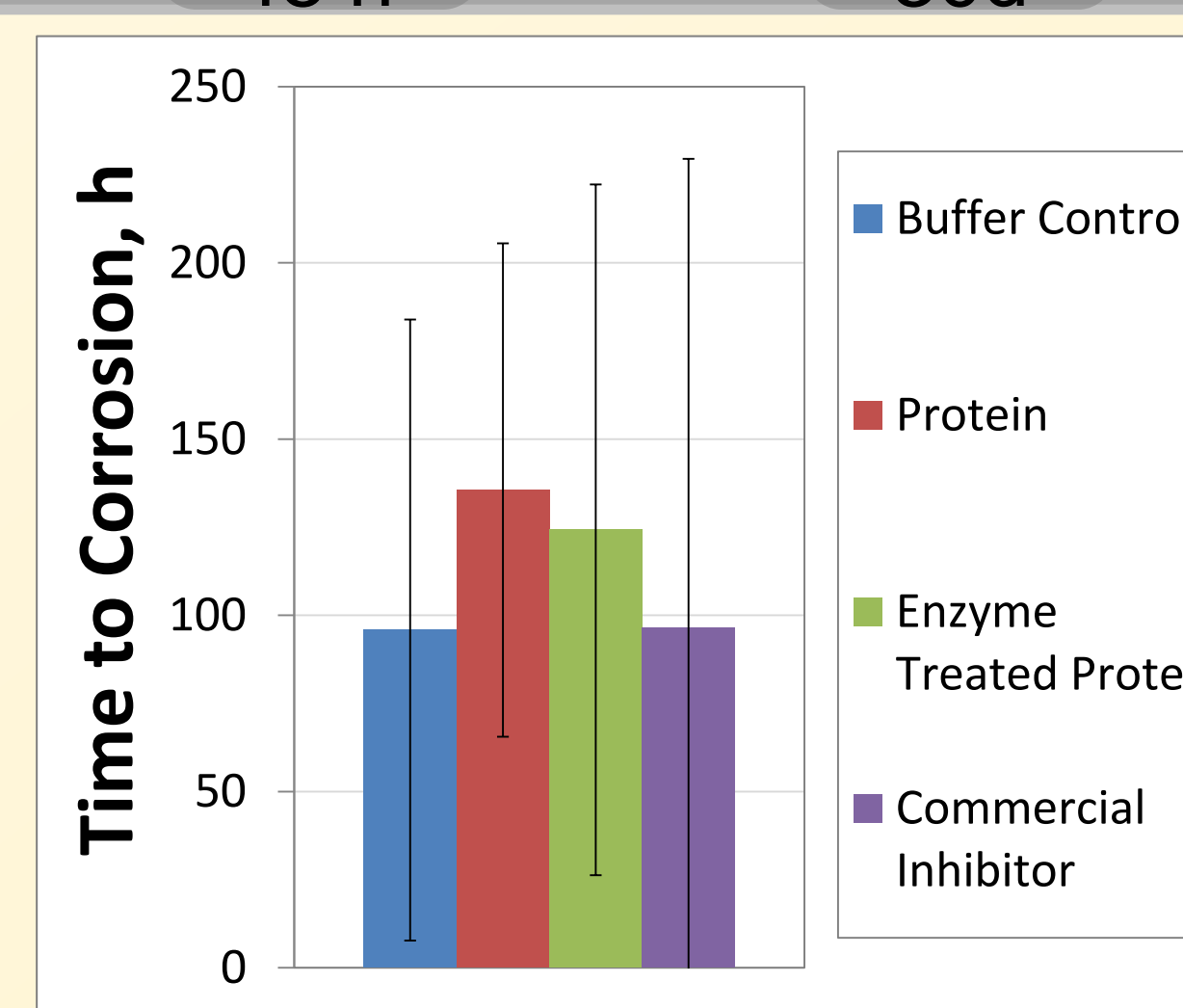
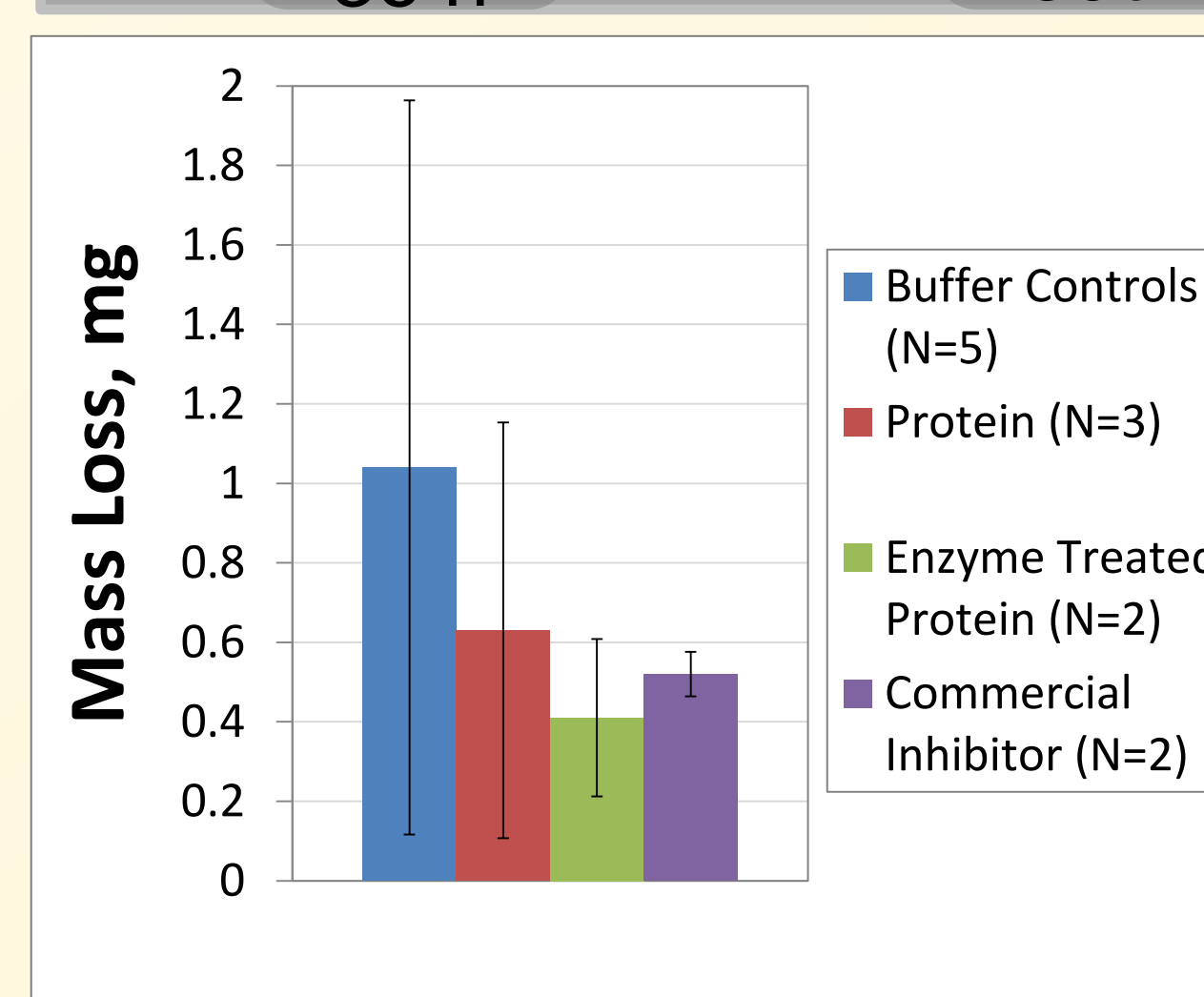
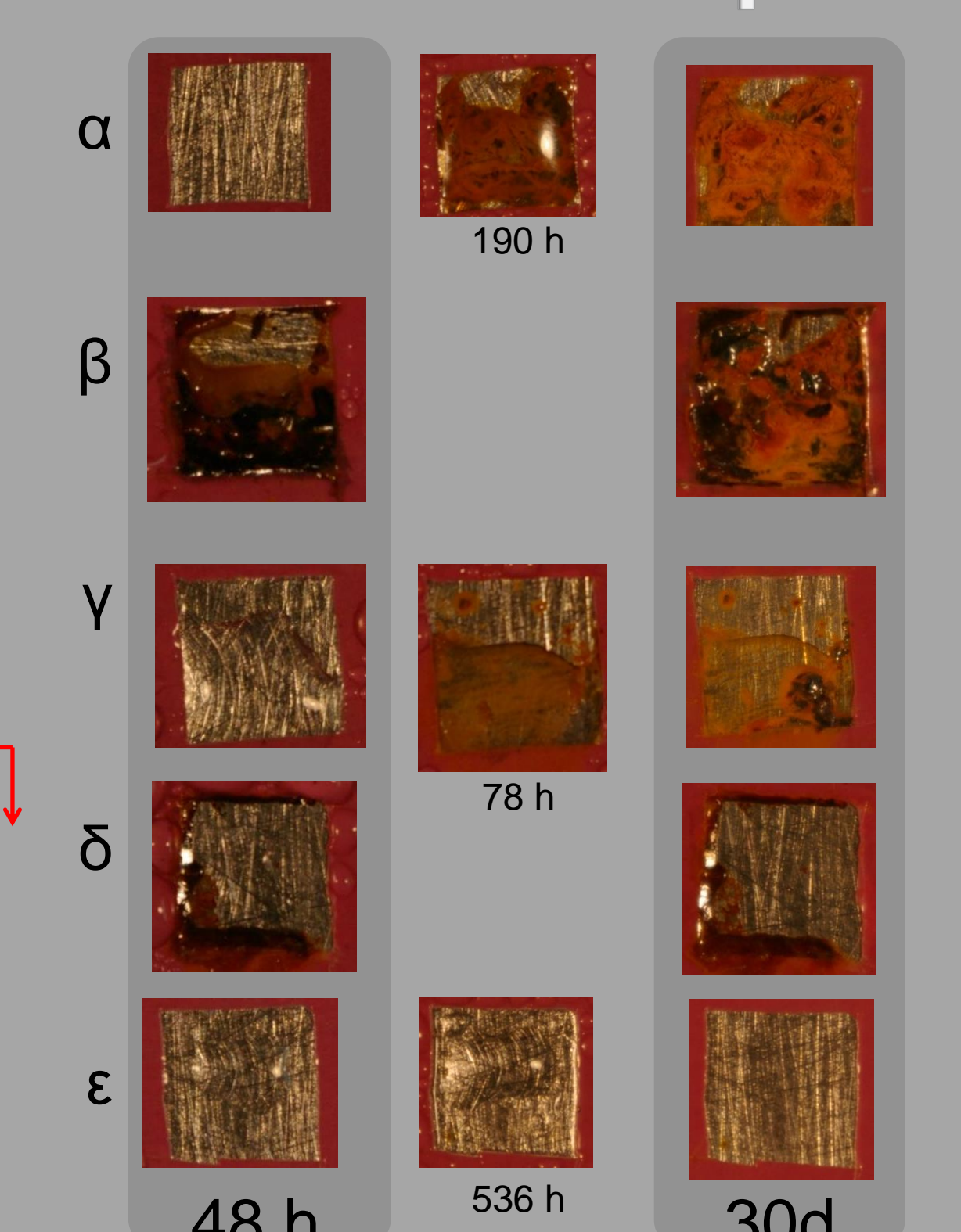
Exposure Chamber Testing

Treated high-strength steel was exposed to a 40°C environment with 100% relative humidity. Pictures were taken of samples to assess the extent and type of corrosion. After 30 days of exposure, the samples were removed and mass loss data was collected to quantify the amount of corrosion.

Protein Samples



Control Samples



Conclusions

- The inconsistent performance of the control samples in both the exposure chamber and the electrochemical tests complicates the analysis of the protein's performance. This variability should be reduced if possible, since no statistically significant effects have yet been found at the protein concentrations used. Pit depth and pit density measurements may help determine whether the protein effectively inhibits corrosion.
- Compared with the buffer controls, the protein treated samples have (on average) a lower mass loss in the exposure chamber and a somewhat smaller charge passed during cyclic polarization.

References

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